

# Energy Storage For Ancillary Services

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## Abstract:

The prices for ancillary services in some markets have frequently been at high levels in recent years, although they have not drawn public attention as did the extreme spikes in electric energy market prices. Spot market prices for regulation and reserves have often exceeded the coincident prices for energy. Energy storage has potential to capture benefits from high ancillary service prices.

A storage unit which can change output immediately and which has very low operating cost when idle is especially well suited to supply reserves and regulation in addition to energy arbitrage. Flow batteries, for example, may have these characteristics. The potential exists for such a storage unit to be in use around the clock as it either charges, discharges, or provides regulation or reserves to the grid. Ancillary services could thus be an excellent application for energy storage. It is desirable to determine the potential operating benefits which an energy storage unit could achieve in promising ancillary services markets.

This paper describes the methods and results of analyzing the potential benefits of using energy storage to provide ancillary services in three independent system operator (ISO) electricity markets. Potential benefits were found in these cases which could justify a substantial capital cost for the energy storage capacity.

## 1. INTRODUCTION

In recent years TVA has investigated several concepts for energy storage to provide bulk power to the grid. These investigations dealt primarily with operating a storage unit to provide energy arbitrage. Within the electric utility industry it was commonly thought that ancillary services, on average, might represent only 5-15 % of total energy costs [1]. However, it was noticed during year 2000 that the hourly prices for regulation and reserves in the New York ISO (NYISO) were often as high as the energy price.

A study was begun to investigate the degree to which high ancillary services prices in NYISO would add value beyond arbitrage and would enhance the viability of energy storage for bulk power applications. After favorable results for NYISO, the study was expanded to also consider ISO New England (ISO-NE) and PJM Interconnection (PJM). The study found provision of ancillary services to be an important role which energy storage can have for a utility. The results were a significant factor in TVA's decision to construct a 12 MW, 120 MWh, energy storage unit at Columbus, Mississippi, using the Regenesys flow battery technology.

Subsequent to this study, other investigation [2] has found that the high prices of ancillary services among ISOs can enable ancillary services to provide a very substantial portion of a generating unit's profit. However, that work did not specifically address the potential for energy storage to provide ancillary services.

## 2. PRICES IN THE ISO MARKETS

Price data were downloaded from the ISO web sites as follows: NYISO, year ending November 16, 2000; ISO-NE, year ending September 29, 2000; and PJM, 6 months ending November 29, 2000. The unweighted average market clearing prices for energy, regulation, and spinning reserves in these markets are shown in Figure 1. The ancillary services prices were uniform throughout each ISO, and energy prices were uniform in ISO-NE. Locational based energy pricing is used by NYISO and PJM, and data was used for the Long Island and Easton zones respectively. These zones were selected because of their relatively high energy prices, in anticipation that higher benefits for energy storage would result. However, the choice of zones proved to be largely irrelevant since the arbitrage benefits were small compared to ancillary services benefits.

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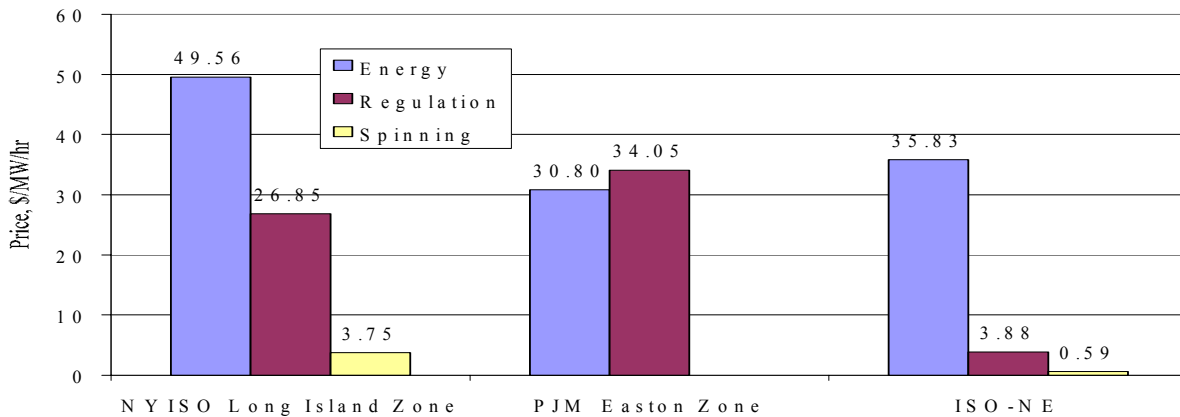


Figure 1. ISO Market Clearing Prices (ca. 2000)

PJM prices for ancillary services other than regulation are not shown in Figure 1 and were not analyzed for two reasons. First, the PJM basis for compensating these ancillary services is different from the bases of NYISO and ISO-NE. Second, PJM prices for other ancillary services were insignificant compared to regulation.

Regulation prices were slightly higher than energy prices in PJM Easton, high but less than energy prices in NYISO Long Island, and considerably lower in ISO-NE. Reserve prices were much lower than regulation.

A provider of ancillary services will in many cases receive added payments beyond the market clearing price, such as opportunity cost or uplift payments, which should be included in any comprehensive analysis. For this initial feasibility study, the added payments were not used except as a sensitivity check in the case of ISO-NE.

Spinning reserve prices in NYISO prior to March 28, 2000, were disregarded in Figure 1 and in the benefit analysis. Prior to then, bidders exercised market power to drive up the price. Corrective action by NYISO led to more reasonable reserve prices afterwards.

Prior to completion of this study, it was reported [3] that regulation prices in NYISO had declined significantly then leveled out. Hence, price data for the three ISOs was reviewed and quarterly averages determined as shown in Figure 2. The decline in NYISO regulation prices was found to have slowed but not ceased as of the dates shown. The decline in NYISO spinning reserve prices after the first two points reflects imposition of

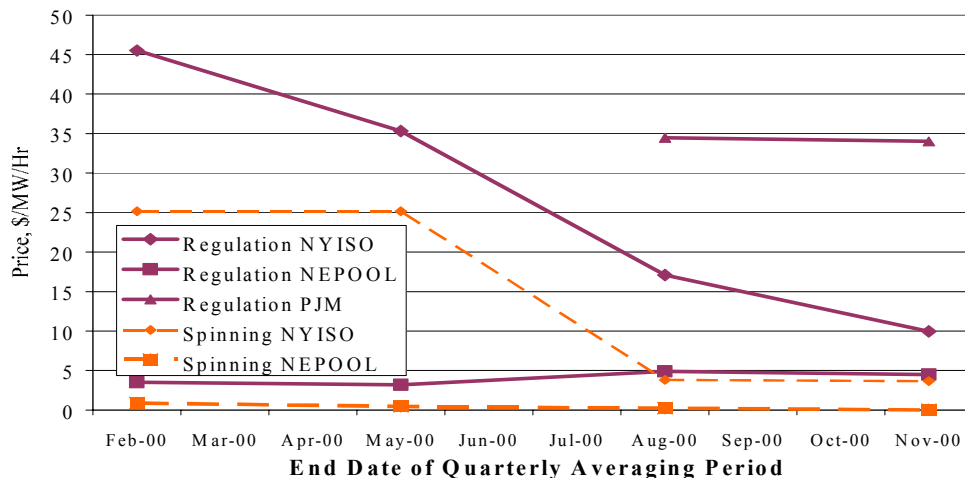


Figure 2. Trends in ISO Ancillary Service Clearing Prices

price caps. In contrast, the available data for ISO-NE and PJM showed no significant overall trends, although there was considerable volatility and apparent seasonal variation.

An example of the daily variation of energy and ancillary services prices is shown in Figure 3 using May 9, 2000. This day was chosen to illustrate the range of variations in prices and modes of operation. Table 1 shows on that date the storage unit would most profitably operate at various hours to discharge, charge, regulate, and provide spinning reserve. On a more typical day, the storage unit would not operate in all those modes.

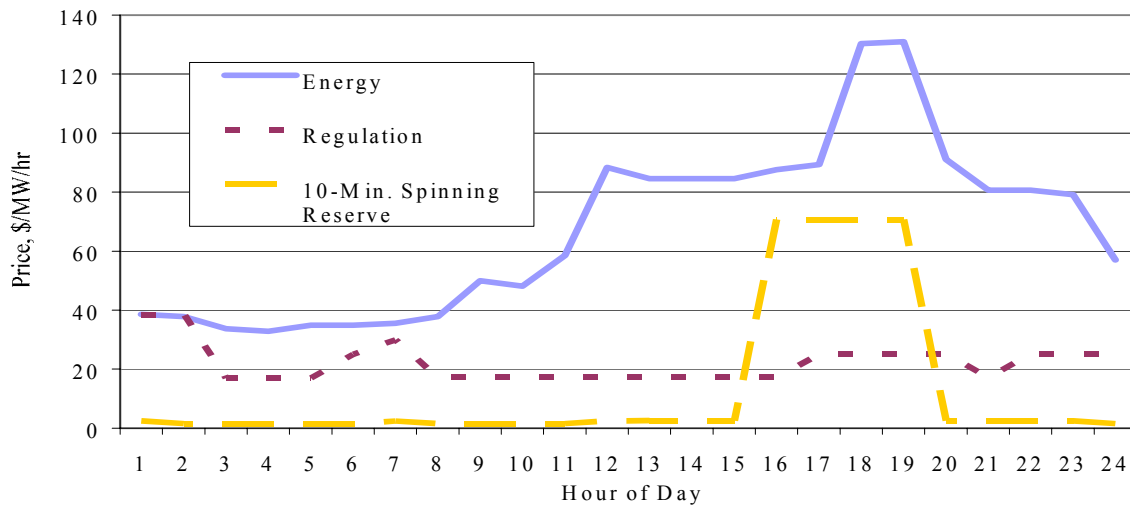


Figure 3. NYISO Long Island Zone Prices for May 9, 2000

Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Discharge												X						X	X	X				
Charge			X	X	X	X	X	X																
Regulate	X	X							X	X	X		X	X	X						X	X	X	X
Reserves																X	X							

Table 1. Variation in Storage Operating Modes for May 9, 2000

### 3. MODEL DESCRIPTION

TVA had previously developed a computer model to analyze hourly operating economics of an energy storage unit which operates for energy arbitrage on a diurnal cycle. That model was extended to also consider use of storage to provide various ancillary services. The model determines on an hourly basis the potential operating profit for each mode (arbitrage, regulation, and various types of reserves), selects the most profitable mode for that hour, and sums results for all hours of the year.

The model values energy and ancillary services at hourly market clearing prices (plus added payments, if desired) using a year of hourly data. Variable revenue and variable operating and maintenance (O&M) costs are calculated for each hour. Perfect foresight of prices for energy and ancillary services is assumed. Other assumptions were made regarding reserves and regulation as described in the following section. The model does not currently address any of the following: fixed costs (such as capital recovery and fixed O&M), transmission losses or constraints, and outages of the storage unit.

In evaluating benefits of providing ancillary services, no attempt was made to mimic the specific rules and procedures of any particular ISO. One reason is that those rules vary among ISOs and are still evolving. Another reason is uncertainty in how the existing ISO rules would apply to the energy storage technologies being considered, which not only can flexibly provide ancillary services as a generator but can also provide ancillary services while charging and presenting a controllable load to the grid. The gross revenue received by storage for providing ancillary services was calculated based on market clearing prices, except for a sensitivity check for ISO-NE. In that sensitivity check, gross revenue for each ancillary service was set at the same rate (including additional payments) paid by the ISO to other generators.

#### 4. COSTS AND REVENUE FOR REGULATION AND RESERVES

When supplying reserves, profitability of operation is affected not only by the price for reserves but also by the probability that the unit is actually called upon to deliver energy and by the amount of payment received for the energy. The model assumes that whenever the storage unit is providing reserves and then is called upon to deliver energy, it will be compensated for the actual cost of delivered energy in addition to the price for supplying reserves. Thus, in the model the profitability of supplying reserves does not depend upon whether the unit is called upon to deliver energy.

In addition to the clearing price for regulation, providing regulation involves other costs and revenues which were not considered in the model. A unit supplying regulation will have its output automatically controlled to deviate up and down around a base value, up to some maximum deviation which is the amount of contracted regulation. By definition, regulation for the grid must average to zero. Most ISOs purchase regulation such that regulation provided by each supplier also averages to zero. However, in some cases up-regulation and down-regulation are purchased separately from different providers. Typically a provider of regulation is paid for the amount of contracted regulation and also paid for the amount of regulation actually provided. No attempt was made in this study to determine the actual amount of regulation provided or its associated revenue.

A storage unit providing regulation with base output of zero will alternately charge and discharge with average output of zero. If the unit had 100% storage cycle efficiency, there would be no net energy consumption. A real unit will incur energy losses while regulating, with the amount of losses depending upon unit efficiency and the amount of regulation actually provided.

While charging, the storage unit can provide reserves equal to its rated power output plus the charging power. The storage unit can provide some regulation while it is charging at part load. If serving an ISO which purchases up-regulation, the storage unit while charging could provide an increased amount of up-regulation just as it could with reserves. These capabilities offer interesting possibilities for bidding strategy which merit further investigation but were not considered in this study.

Due to these complexities of regulation and reserves, the model currently makes the simplifying assumption that off-peak charging for arbitrage does not impact profit from providing either regulation or reserves. Sample sensitivity checks were done for the impact of charging upon regulation profit. The checks found that this assumption had only a minor effect on overall calculated benefits where regulation was the dominant mode (NYISO and PJM), but could be more significant for ISO-NE. The model also neglects net energy loss and variable O&M while providing regulation.

#### 5. INPUT PARAMETERS FOR ANALYSES

Energy and ancillary services price data were used for the three ISOs and their respective time periods as described previously. A period of 52 weeks (364 days) was used to be consistent with other TVA long range modeling. The storage unit was assumed to have 65% efficiency, 9 hours of storage (the maximum usable in a diurnal cycle at 65% efficiency with hourly increments), variable O&M of 1 \$/MWh, and operating power level the same whether charging or discharging. All analyses were done on a per installed MW basis. The 6 months of data for PJM was used twice to get annualized results.

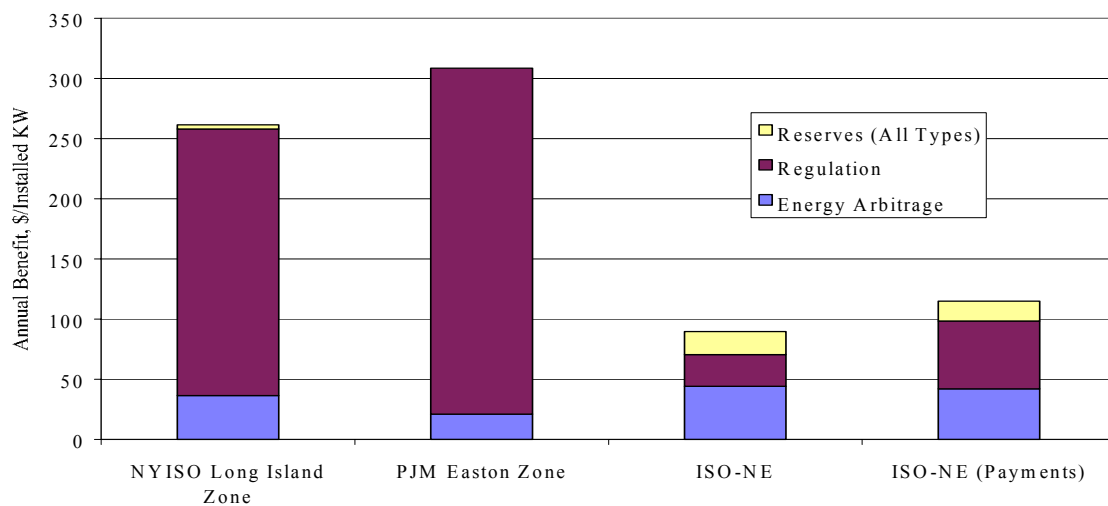
## 6. RESULTS OF ANALYSES

The number of hours for which a given operating mode was the most profitable choice for storage operation is shown in Table 2. For all three cases, regulation is by far the most frequent choice, followed by arbitrage and then reserves.

	Regulation	Energy Arbitrage	10 Minute Spinning Reserve	10 Minute Non-Spin Reserve	30 Minute Operating Reserve	Ties
NYISO Long Island Zone	7871	734	135	6	8	18
ISO-NE	6858	952	690	281	23	68
PJM Easton Zone	8444	292	NA	NA	NA	0

**Table 2. Annual Frequency of Selection as Most Profitable Mode**

The annual total operating benefits for the three ISOs are shown in Figure 4. The results reflect the prevailing prices in each market (Figure 1), as may be seen by contrasting the benefits for ISO-NE with the other two markets. Regulation provides the dominant benefit in the PJM and NYISO cases. For ISO-NE, the regulation benefit is much smaller than in the other markets but is still substantial relative to energy and reserves. The benefit available by providing reserves was noticeable only in the ISO-NE case.



**Figure 4. Storage Operating Benefits in Ancillary Services Markets (ca. 2000)**

Another case was investigated to determine the potential impact upon benefits if other payments (in addition to clearing price) for ancillary services were taken into account. ISO-NE was investigated because necessary data was available on that web site and because the benefits in ISO-NE were much lower than in the other two ISOs. The results for this case are labeled ISO-NE (Payments) in Figure 4. Accounting for other payments increased the overall benefits by 30%.

A test case was run to estimate the impact of the decline which had been observed in regulation prices in NYISO during the period of analysis. In the test case, regulation prices were set constant at the average value which had existed in the last quarter of the period analyzed. That change caused the overall benefits of storage to decline by about half.

## 7. CONCLUSIONS AND RECOMMENDATIONS

This study found potential annual operating benefits high enough to justify a substantial capital cost of energy storage for providing ancillary services. Future prices of ancillary services are key to whether such benefits can actually be attained. Those prices are quite uncertain, particularly because of ongoing evolution in ISO markets. However, even if future ancillary service prices were to decline substantially from those in 2000, energy storage could still be profitable, especially as the capital costs of new storage technologies decline.

In addition to supplying energy and ancillary services to the grid, energy storage may be used to enhance the operation of renewable energy sources such as wind [4]. In such an application, there may be additional benefits which should be considered when determining the overall benefits of energy storage.

Future work is recommended in three areas:

1. Assess the impacts of changes in market prices for ancillary services after this study.
2. Address in more detail the most profitable bidding strategies and operating modes by which storage can provide ancillary services and arbitrage in ISO markets.
3. Ensure that future electricity market designs do not unfairly hinder the profitable use of energy storage.

The third area of recommended work addresses a real concern that can impact deployment of any new generation technology which has unconventional performance characteristics. For example, wind energy as an intermittent resource has suffered from punitive imbalance tariffs, and wind proponents have found it necessary to perform various tests and studies in an effort to win relief from such tariffs and other rules [5].

The Federal Energy Regulatory Commission (FERC) has announced [6] it will issue a notice of proposed rulemaking (NOPR) this summer which will set guidelines for standardized market design and transmission service. The supporting FERC working paper [7] states that additional scheduling options may need to be developed to address the special conditions facing energy-limited resources such as hydroelectric power and environmentally constrained thermal power. The latest energy storage technologies have much more operational flexibility than either non-storage units or established storage technologies such as pumped hydro. The capabilities of new storage technologies need to be taken into consideration as the additional scheduling options are developed. Energy storage stakeholders would do well to become involved in this FERC rulemaking to encourage development of guidelines which will allow the fullest economical use of energy storage units.

## 8. REFERENCES

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